

Reduction of Threading Dislocations in RF-MBE Grown Polarity Controlled GaN by AlN Multiple Interlayer

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Crystal quality of polarity controlled GaN, both in Ga- and N-polarities by RF-plasma assisted-molecular beam epitaxy (RF-MBE) was improved by introducing the high-temperature grown AlN multiple-interlayer (AlN-MIL). The type of threading dislocation (TD) and propagation behavior in both polarity of GaN was characterized by transmission electron microscope (TEM) observation. In N-polarity GaN, a mix dislocation with nature of edge character and spiral one was dominant. This dislocation decreased remarkably in 1/10, by passing through AlN-MIL, where TDs tend to bend largely and join together above AlN-MIL and to terminate in the interface of AlN-MIL. As a result, N-polarity GaN showed the highest electron mobility of $668 \text{ cm}^2/\text{Vs}$ at carrier density of $9.5 \times 10^{16} \text{ cm}^{-3}$. Meanwhile, in Ga-polarity GaN, the edge dislocation was dominant. TEM study clearly showed that AlN-MIL acted as block of propagation of TDs and the reduction of TDs was obtained.

GaN layers were grown on (0001) sapphire substrates by RF-MBE. N-polarity GaN was obtained by optimized initial nitridation of sapphire substrate, while Ga-polarity GaN was achieved by high temperature grown AlN buffer layer. The AlN buffer and AlN layers in AlN-MIL were grown by migration-enhanced-epitaxy (MEE). In the N-polarity, GaN was grown by MEE, inserting AlN-MIL with 5pairs of 8nm AlN (see Fig.2). On the other hand, in Ga-polarity, GaN was grown by shutter-controlled-method [1], where the 18 pairs AlN-MIL containing six 8nm AlN and twelve 2nm AlN layers, was inserted (see Fig.3). These samples were evaluated by cross-sectional TEM. The edge dislocation dominated in Ga-polarity GaN (about 80%), and the mix dislocation dominated in N-polarity GaN (about 50%). It was observed that TDs terminated remarkably in AlN-MIL for both polarity of samples, and in N-polarity GaN, TDs bend largely and join together above AlN-MIL. The dislocation densities were evaluated in regions of 200nm above AlN layer and near surface. The former is performed by TEM observation, and the latter by photo-electro-chemical wet etching [2]. It was confirmed that TDs decreased about 1/10 in N-polarity GaN. The dislocation density of N-polarity GaN near the surface was $2 \times 10^9 \text{ cm}^{-2}$. For the Ga-polarity GaN, most of dislocations are propagated without joining together. The difference in dislocation reduction degree between different polarities is probably caused by the dislocation component difference. That is due to that the N-polarity GaN contained spiral component more than in Ga-polarity GaN.

The N-polarity sample marked the highest electron mobility of $668 \text{ cm}^2/\text{Vs}$ at carrier density of $9.5 \times 10^{16} \text{ cm}^{-3}$ (see Fig.1). This is the highest value for RF-MBE grown GaN without GaN template as long as we know. After etching the N-polarity layer in $0.7 \mu\text{m}$ by HCl, the electron mobility decreased down to $250 \text{ cm}^2/\text{Vs}$. It suggests that the high mobility ($668 \text{ cm}^2/\text{Vs}$) was resulted from reduced dislocation area near the surface.

References

- [1] A. Kikuchi et al., J. Cyst. Growth, 189/190 (1998) 109-113.
- [2] C. Youtsey et al., Appl Phys Lett., Vol.73, (1998) 797-799.

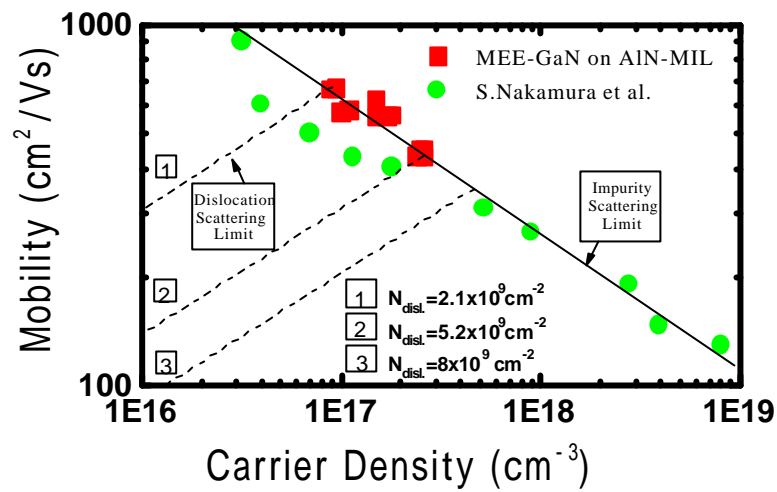


Fig.1 Mobility vs. Carrier density

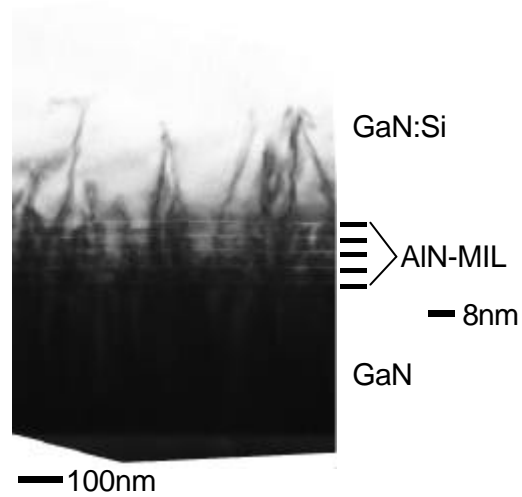


Fig.2 Cross sectional TEM of N-polarity GaN sample

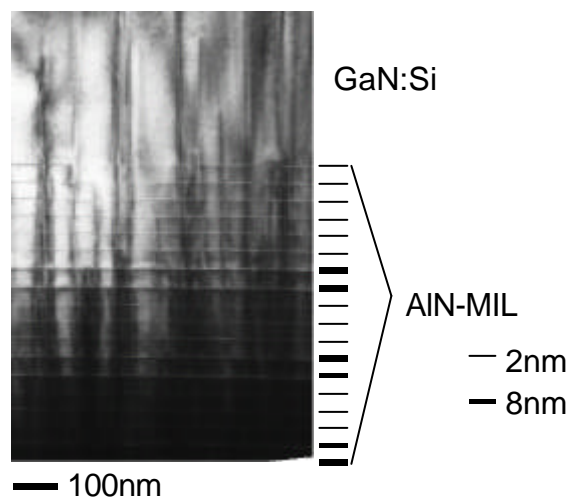


Fig.3 Cross sectional TEM of Ga-polarity GaN sample